

AN EVALUATION OF A  
RASTER SCAN DISPLAY FOR  
SIGNAL PROCESSING AND ANALYSIS

William R. Teetz

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REPORT

# NAVAL POSTGRADUATE SCHOOL

Monterey, California



## THESIS

AN EVALUATION OF A  
RASTER SCAN DISPLAY FOR  
SIGNAL PROCESSING AND ANALYSIS

by

William R. Teetz

December 1976

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The CONOGRAPHIC-12 display terminal is a viable option to be considered in this application. However, several features that are commonly available on the Hughes CONOGRAPHIC-12 terminal were not considered useful in this study and therefore were not utilized or evaluated.





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Raster Scan Display  
for  
Signal Processing and Analysis

by

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Submitted in partial fulfillment of the  
requirements for the degree of

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## ABSTRACT

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The purpose of this study was to evaluate the Hughes CONOGRAPHIC-12 graphics display terminal as a signal processing and analysis tool. Utilization of computer controlled graphics terminals is part of an effort to provide necessary data to the signal analyst in a more usable form than is presently available. The work described herein was part of a continuing program at the Naval Postgraduate School to support acoustic signal analysis. The direction presently being taken in this program is to evaluate newer, smaller, more modern and less expensive hardware in this environment.

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## CONTENTS

I. INTRODUCTION.....	7
II. BACKGROUND.....	9
III. HARDWARE DESCRIPTION.....	16
A. HOST COMPUTER.....	16
B. CONOGRAPHIC-12 HARDWARE.....	17
IV. SOFTWARE DESCRIPTION.....	22
A. DESIGN CONSIDERATIONS.....	22
B. VARIABLE PARAMETERS.....	25
1. Transform Length, Lag and Sampling Rate.....	25
2. Data Start Time.....	25
3. Display Time.....	26
4. Frequency to be Displayed.....	26
5. Scale Factor.....	26
6. Display Resolution.....	27
7. Angle Offset.....	27
8. Number of Lines.....	27
9. Vertical Separation.....	28
10. Highlight.....	28
C. HIDDEN LINE REMOVAL.....	29
V. EVALUATION.....	34
VI. CONCLUSIONS AND RECOMMENDATIONS.....	40
APPENDIX A - USER'S MANUAL.....	43



BIBLIOGRAPHY..... 52

INITIAL DISTRIBUTION LIST..... 54





## I. INTRODUCTION

The purpose of this study was to provide an evaluation of a raster scan graphics display terminal, the CONOGRAPHIC-12, in signal processing and analysis. Visual analysis of acoustic signals is an important part of current defense efforts. The primary method presently in use in the Navy for providing the necessary information for analysis is the lofargram. Drawbacks in this medium, however, provided the impetus to investigate other means of displaying the data for analysis.

The use of computer controlled graphics terminals as an alternate display medium is being investigated at the Naval Postgraduate School. An early effort in this area resulted in the SPOTLIGHT system (Signal Processing of Time Lines by Graphical Techniques) [1]. SPOTLIGHT is a signal processing display system designed to improve signal identification by means of a time-frequency-amplitude orthogonal display. A selected frequency search is employed in this system to provide high gain in frequency intervals of interest. The operator may control the frequency interval, amplitude scaling, movable cursors or highlights, and various other parameters to provide an effective display of the requested data. In addition, a hidden line removal algorithm was included that reduced the clutter caused by line intersections.



The original implementation of SPOTLIGHT utilized a graphics terminal that required continual refresh data from the host computer. Thus, the amount of signal information that could be displayed was limited by the time required to provide the necessary data to refresh the display. The display of acoustic signal data as generated by the SPOTLIGHT system was well received by personnel who would be users of the system. The enthusiasm for the SPOTLIGHT system provided the necessary impetus to investigate the feasibility of implementing a similar system on hardware that would be more practical for large scale use. Smaller physical size, lower initial and maintenance costs, and greater reliability were some of the goals which were to be met in the subsequent implementations. A mini-computer, such as the Navy's AN/UYK-20, controlling a small general purpose display terminal appeared to meet those specifications. Since an AN/UYK-20 computer was not available to control the CONOGRAPHIC-12 terminal in this study, a PDP-11/50 [2] mini-computer was substituted in its place.

The substitution of a PDP-11/50 computer in this evaluation introduced the necessity of determining the capabilities of the processor and peripheral equipment necessary for the implementation, as well as the evaluation of the terminal itself.



## II. BACKGROUND

As indicated previously, the primary medium presently utilized in the Navy for acoustic signal analysis is the lofargram. The lofargram is produced as a series of lines of varying intensity on heat sensitive paper. The pen or stylus which produces the line has an electrical signal applied to it which is proportional to the amplitude of the input signal. As the stylus produces a line on the paper, a specified frequency spectrum is displayed. The line as drawn provides a representation of frequency verses amplitude. The series of lines, each separated in time by a specified increment, provides a representation of time in the lofargram display. The lofargram is thus a display of frequency, amplitude and time.

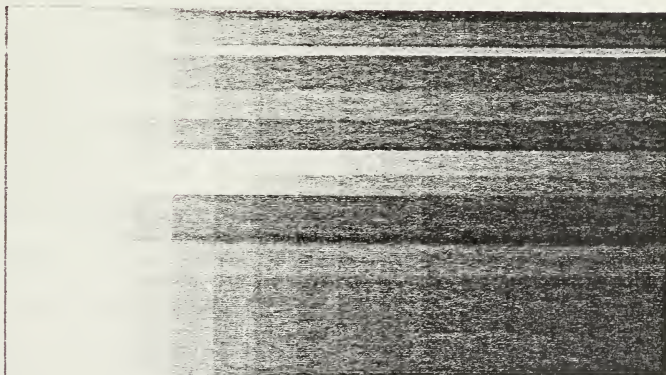


figure 1: The Lofargram Medium



while frequency and time are easily recognizable, the only visual distinction between variations in amplitude is the change in the intensity of the line as drawn on the gram (figure 1). One of the major limitations of the lofargram is the representation of input signal amplitude on the gram since slight variations in signal amplitude may not provide noticeable changes in line intensity. Detection of variations in line intensity represented by varying shades of grey also presents a problem since determination of differences in shades of grey is one of the human's weakest sensory capabilities [3]. In addition, for the analyst to distinguish between the variations produced by random background noise and actual changes in the signals of interest, sufficient time must elapse to allow recognition of a trend as it occurs. However, viewing the gram over a period of time further decreases the analyst's ability to distinguish between shades of grey. Thus, the abilities of even a trained analyst are time limited by visual fatigue when viewing the lofargram.

In an attempt to provide a display medium which would increase the analyst's useful time and provide the same data as the lofargram in a form that would allow easier detection of slight variations in signal amplitude, the use of computer controlled graphics terminals is being investigated at the Naval Postgraduate School. The use of a graphics terminal allows a two dimensional display of frequency verses amplitude to be produced (figure 2). This type of display





provides a format for the data in which variations in signal amplitude are easily recognizable. The presentation of a single line does not, however, incorporate the third dimension (time) which is available on the lofargram. Time as a dimension of the display is necessary for the ready detection of trends in amplitude variations of a particular signal. To provide a time dimension on the graphics terminal display, several lines, each showing the specified frequency spectrum at a different time, were drawn on the screen (figure 3). This display format, known as a time-frequency-amplitude orthogonal or "waterfall" display, provides the three pieces of information or dimensions required by the analyst. Variations in amplitude between adjacent signals, or in the same signal in adjacent time periods, are presented for analysis.

The SPOTLIGHT system was implemented in a research environment on equipment that was too large, too old and too expensive for large scale use. In addition, the amount of information that could be displayed at one time was limited by the need to continually refresh the terminal. However, initial enthusiasm for the SPOTLIGHT system provided the impetus to commence a program to investigate the feasibility of implementation of a SPOTLIGHT-like system on more modern, smaller and less expensive equipment.

The desire to implement the system on a minicomputer without the requirement for excessive memory dictated that refresh requirements of the display be minimized. Thus, the



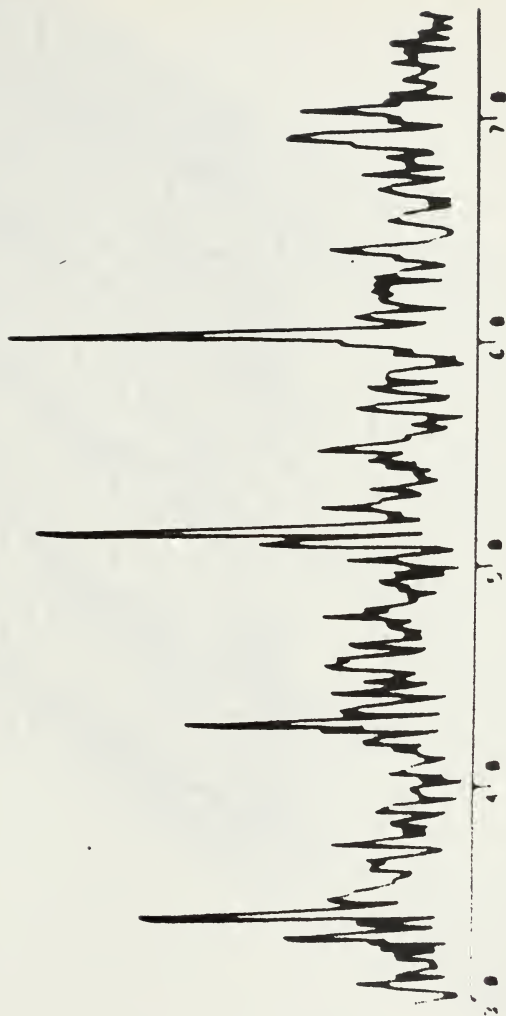


figure 2: Frequency verses Amplitude Display



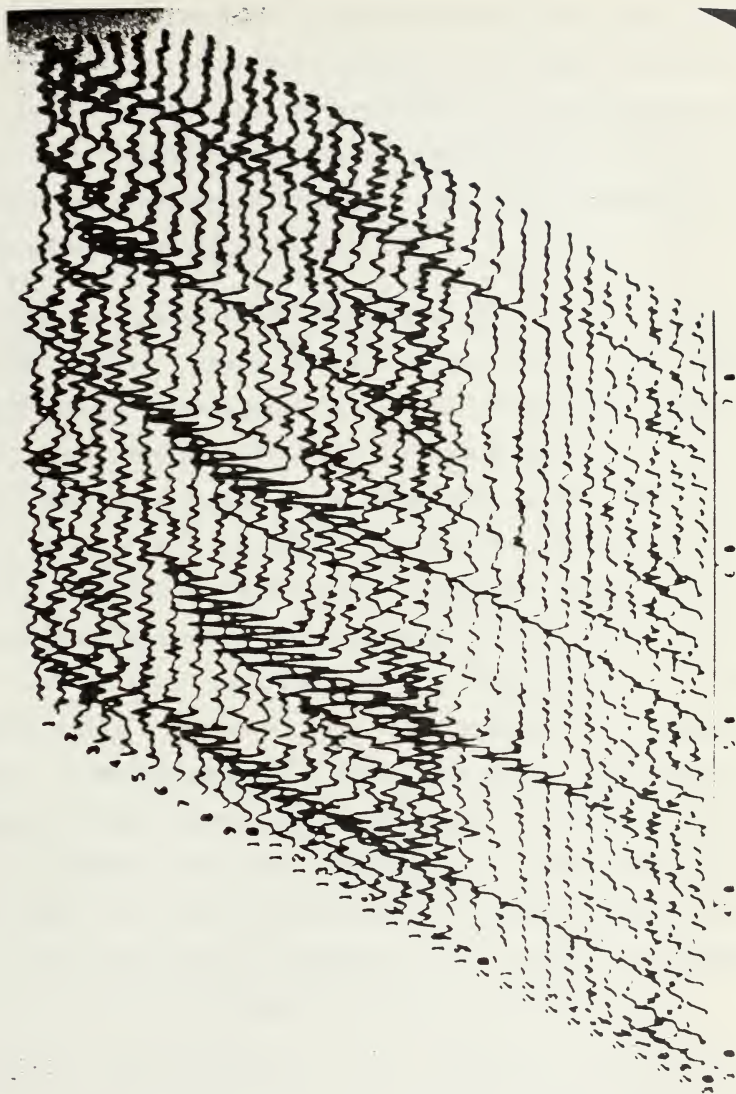


figure 3: Waterfall Display



use of storage type displays was investigated. The first storage type display to be investigated and evaluated was a Tektronix 4014-1 graphics terminal interfaced to the PDP-11/50 computer [1]. This combination of a minicomputer controlling a direct view storage tube display proved to be feasible and presented a viable option to be considered for signal processing and analysis.

An alternate storage tube display which was available at the Naval Postgraduate School was the Hughes CONOGRAPHIC-12 display terminal. This terminal has capabilities which are significantly different from the Tektronix 4014-1, but which appear to be compatible with the objectives of the SPD program. As with the Tektronix 4014-1 display, the need for continual refreshing from the host computer was eliminated by the CONOGRAPHIC-12 display terminal. Of primary interest in the evaluation of the CONOGRAPHIC-12 terminal were the effects of a static display, drawing speeds, host computer requirements, response to user commands and the features available on this display terminal which were not available on previous implementations. The term static display as used throughout this study may be defined as a display which cannot be changed without erasing and redrawing the entire image.

Input data available for this evaluation was preprocessed and stored on magnetic tape using methods developed for SPOTLIGHT. This preprocessing of the raw acoustic data includes of performing Fast Fourier Transforms (FFT) on the





data, producing a representation of the power in the input signal. The resulting data format is affected by three parameters utilized in the processing. These parameters are length of the FFT, delay between FFT's and the sampling rate. For further information on the effects of FFT processing on the input data, the interested reader is referred to Refs. 4,5,6,7,8 and 9. .



### III. HARDWARE DESCRIPTION

#### A. HOST COMPUTER

The host computer system utilized in this implementation consisted of two Digital Equipment Corporation (DEC) PDP-11/50 processors, a 7-track magnetic tape transport, a Control Data 9762 series disk storage unit, a Datamedia 2500 alphanumeric terminal, and the CONOGRAPHIC-12 graphics display terminal. The use of two PDP-11/50 processors was necessitated by the particular configuration which existed at the time that the evaluation was conducted. One processor was interfaced to the CONOGRAPHIC-12 while the other one was interfaced to the tape transport. Both processors are interfaced to the disk storage unit which provided a convenient path for data transfer. After the data was read and stored on the disk unit by one processor, the other utilized the stored data to provide information to the display as desired.

Both PDP-11/50 processors operate under the UNIX operating system which was developed at Bell Telephone Laboratories, Inc [10]. The UNIX operating system provides for a multi-user environment but most evaluation and testing were accomplished while no other users were active. When operating with other users active, the execution of the program was slowed to some extent depending on the CPU loading by



other processes. Since much of the time during which the program is active is spent in user analysis of the displayed picture, the slower operation has little detrimental effect.

The minimum hardware configuration required for the implementation of this system consists of the following:

1. A mini-computer with capabilities similar to those found in the PDP-11/50 [2].
2. Approximately 48K of core memory available to the user. This requirement could be lessened if paging or segmentation was supported by the computer's operating system.
3. A means of data input. In this study, a magnetic tape transport was required since all available data was stored on magnetic tape.
4. An auxilliary storage unit to provide a capability for recall of previously displayed data. A disk unit was used in this study for increased data access speed over tape storage and due to the hardware configuration that existed.
5. The CONOGRAPHIC-12 display terminal.

#### B. CONOGRAPHIC-12 HARDWARE

The CONOGRAPHIC-12 display terminal, as installed at the Naval Postgraduate School, consists of a high resolution television monitor and a video memory. This terminal includes the hardware to draw vectors or straight lines and a character generator. Unusual features in the CONOGRAPHIC-12 terminal include the necessary hardware to



draw conic sections and perform selective erasure. The hardware conic section drawing capability results in the ability of the terminal to produce curved lines on the screen rather than the straight line approximations of curves commonly found with other systems. In this study, however, the curve drawing capability was not utilized or evaluated since previous research had shown that straight lines produce an enhanced image for signal analysis. The selective erase capability allows parts of the displayed image to be removed without affecting the rest of the image. This capability was initially considered for use. However, it was not employed in this study for reasons that will be more fully explained in the Hidden Line Removal section of this thesis.

The video memory utilized in this system was a Hughes type H-1269A Scan Converter Tube [11,12]. The scan converter tube is similar to a standard cathode ray tube and basically consists of an electron gun, appropriate focusing and deflection mechanisms and a storage target. The image to be stored is described by X-Y positional data and transmitted by the host computer to the scan converter. The transmitted data causes appropriate beam deflections over a square inscribed on the storage target. Stored information is read by a raster scan and a copy is displayed on the high resolution television monitor.

The storage medium consists of a grid-like metallic backing electrode deposited on an insulator substrate. The





dielectric exposed by the metallic grid forms discrete storage elements, and the collection of storage elements make up the storage target. In the WRITE mode, an electron beam is moved across the storage target as required to produce the desired image. Positive charges remain on the storage target in the wake of the beam as a result of the secondary emission characteristics of the dielectric medium. The positive charges which remain are subsequently detected in the READ mode by distinguishing the difference of potential between the storage element surface and the backing electrode. This potential difference is utilized to modulate the signal applied to the electron beam which scans the viewing screen. In producing the display image, the entire viewing screen is scanned by a raster scan in a manner similar to that found in commercial television sets.

Another feature of the CONOGRAPHIC-12 terminal that was different from most graphics terminals was the ability to produce dark lines on a light background as well as light lines on a dark background. The "black-on-white" display mode was the normal mode of operation for the CONOGRAPHIC-12 terminal and the resulting display appeared to be less affected by variations in ambient light surrounding the terminal.

A feature of the CONOGRAPHIC-12 terminal that added a new dimension to signal analysis was the zoom capability. The zoom feature varied the effective area to be scanned on the storage target and hence the image displayed on the





figure 4: Example of Zoom Display



screen. Three controls were available for the user to operate. The use of these controls does not affect in any way the actual image that was stored on the storage target, only the copy on the monitor screen is varied. The three controls were a joystick for positioning, a gain control to change magnification, and an on/off switch to activate or deactivate the zoom feature. With the joystick, the user may position the scanned area over any portion of the storage target that was desired. The gain control allowed the displayed portion of the storage target to be effectively magnified by up to six diameters. The on/off switch allowed the user to switch back and forth from normal display to a prepositioned zoomed display without modifying the image in either mode. Since the stored image is not modified in any way by the zoom feature, no loss of detail occurred when the picture was magnified. In fact, details that were hard to distinguish in the normal mode may become more readily discernable when in the zoom mode. The zoom feature thus provided a significant advantage over the terminals utilized in previous implementations of SPOTLIGHT.



#### IV. SOFTWARE DESCRIPTION

##### A. DESIGN CONSIDERATIONS

The primary objective of this study was to evaluate the capabilities of the CONOGRAPHIC-12 graphics display terminal for signal processing and analysis. To accomplish this evaluation, new software, tailored to meet the requirements of the CONOGRAPHIC-12 terminal, was needed. The objective of the software design was to provide a display of information similar to that found in the original SPOTLIGHT implementation. In addition, the software was to be as logically simple as possible and require a minimum amount of main memory for execution. These requirements were dictated by the desire to provide a system which could be implemented on a minicomputer with minimum memory requirements. The software for this project was written in the high level programming language C which was developed by Bell Telephone Laboratories, Inc [13]. The C language is a structured language and incorporates many features suitable for system development work. The system on which SPOTLIGHT was originally implemented required that a considerable portion of the programming to be done in assembly language. All programming for the PDP-11/CONOGRAPHIC-12 implementation was done in the C language. The use of this structured language facilitated the implementation of the software developed





during this evaluation on other computer systems. Subroutines which constructed the actual data format necessary to control the CONOGRAPHIC-12 had been previously developed at the Naval Postgraduate School, and were also utilized in this implementation [14].

The display format and user interaction capabilities of the original SPOTLIGHT system were the standards for comparison when evaluating the display of the CONOGRAPHIC-12 system. To meet the display format goal, a waterfall display was required. Due to the non-dynamic nature of the CONOGRAPHIC-12 terminal, the actual construction of the display was considerably different. On the CONOGRAPHIC-12, the entire picture was constructed before it was drawn on the screen. This included accessing all necessary data from the input data file, performing necessary calculations for hidden line removal and transmitting the requested information to the terminal. To provide a display with the same time relationship between adjacent frequency spectrums, the input data file was accessed in reverse time sequence, and the picture was drawn in reverse time sequence also. This was necessitated by the algorithm utilized for hidden line removal (see section C - HIDDEN LINE REMOVAL). To provide the desired amount of user interaction and overall program generality, several parameters were made available for user control. This interaction provided the flexibility necessary for the user to tailor the display to meet his needs. The amount of user interaction necessary to actually obtain



a picture was minimized so that the user would not find this system too difficult to operate. The combination of ease of operation and flexibility of control provide rapid response and a powerful display format, prime concerns for the design of any computer graphics system [14].

To minimize the need for user interaction, initialization values for operation of the program are limited to those necessary for correct data interpretation. The parameters required for initialization include the transform length, lag between transforms, sampling rate and data starting time. Common values for transform length, lag and sampling rate were provided as default conditions which further reduced the actual input requirements at analysis start time. Additional flexibility in this implementation was provided by allowing the user to modify certain parameters during execution. When in the command mode, a listing of the various parameters with their current values was provided for user selection. When a parameter was selected, the input value was checked for validity before allowing the user to continue. The parameters set during initialization affect the data and its interpretation by the program while the other parameters control the actual display of the data. The effect that each parameter has on the data or display will be covered briefly in the following section. A more detailed explanation of the parameters including the format for entry, allowable values, and effect on the display, may be found in the User's Manual (Appendix A).



A 'help function' is designed to provide on-line assistance to the operator in a user's manual format. This feature is desirable in any interactive system, and provides the user with readily available assistance. Subjects covered in the help function as implemented in this system include formats for data entry, allowable ranges for parameters, normal values, and a brief description of the effects of the parameters on the display. Although not incorporated at this time, additional help function subjects could include information to aid the user in the analysis of the displayed information.

## B. VARIABLE PARAMETERS

As previously mentioned, a wide variety of parameters are made available to allow the user to tailor the system to meet his needs in the analysis environment. A brief explanation of each of these parameters follows.

### 1. Transform Length, Lag and Sampling Rate

These parameters are directly related to the format of the input data and are required for correct interpretation of the data. They are set during initialization and remain fixed throughout execution.

### 2. Data Start Time

The data start time is the time reference utilized throughout the program. It is also set at initialization



and remains fixed throughout the execution phase of the program. To enable real times to be utilized during execution of the program, the actual time of the start of the data should be entered.

### 3. Display Time

Display time is the time on which each requested waterfall display is based. The topmost frequency spectrum on the display is associated with the entered display time. By varying the display time, the user may examine signals of interest occurring at any time in the input data.

### 4. Frequency to be Displayed

The frequency to be displayed appears at the left margin of each frequency spectrum on the screen. Frequency increases to the right along the horizontal axis. The maximum frequency that may be displayed is limited by the input data. By varying the frequency to be displayed in conjunction with the display time, the user may access all of the available data.

### 5. Scale Factor

Scale factor applies a scaling factor to the data as read from the disk storage unit. Varying the scale factor varies the amplitude of the displayed signals. Varying the scale factor does not change the relative amplitude of adjacent signals, but varies all in the same proportion.





## 6. Display Resolution

The display resolution parameter provides a horizontal scaling factor for the user. It directly affects the bandwidth of the frequency spectrum that is displayed.

## 7. Angle Offset

The angle offset parameter allows the analyst to skew the display to minimize the effects of hidden line removal on signals of interest which might otherwise be hidden. It may also be utilized to determine the changes in signal amplitude over a period of time.

## 8. Number of Lines

The number of lines to be displayed provides another aid in the analysis of input data. A maximum of 30 lines may be displayed at one time. This is a considerable increase over the number of lines available at one time in the original version of SPOTLIGHT. If a single line is desired, additional features of the program are enabled. In the single line mode, the user has the opportunity to inspect the time behavior of selected signals which are in the spectrum being displayed. This feature provides an additional means for determining variations in signal amplitude over time other than that provided by the angle offset feature.



## 9. Vertical Separation

This parameter provides a vertical scaling factor to the display. This factor only affects the vertical separation between adjacent frequency spectrums and does not affect the amplitude of the signals in any way. Increasing vertical separation allows the user to spread the displayed spectrum out sufficiently to eliminate all hidden line removal problems. By spreading the display, however, the number of lines that may be displayed at one time decreases proportionally. A compromise between separation and number of lines must be reached by the user depending on the data to be presented.

## 10. Highlight

The highlight feature of this implementation is designed to provide the user with a frequency reference mark on the display. It provides a region of increased intensity of each frequency spectrum at the same frequency. The width of the intensified area is also controllable by the user. This feature is particularly helpful in maintaining visual continuity of a frequency when an offset from vertical is being utilized.



## C. HIDDEN LINE REMOVAL

One of the unique features of the SPOTLIGHT system was the capability of providing hidden line removal. Hidden line removal provides increased analysis efficiency and a reduction in visual fatigue by markedly reducing the image complexity. Therefore, a means of providing hidden line removal in the CONOGRAPHIC-12 implementation was required. Each frequency spectrum that was displayed to the user was a unique element in the total picture and it should be obvious which portions of the display are associated with each spectrum. To provide this capability, each spectrum was treated as if it were the edge of an opaque surface. Thus, the display may be thought of as a stack of planes, one in front of another. Where one plane obscures the edge of a plane behind it, the affected section of the obscured plane must be removed from the displayed picture. Two means for providing this hidden line removal were available on the CONOGRAPHIC-12 system. The capability of performing selective erasure which was a part of the hardware was first considered. Utilization of the selective erase capability would allow the frequency spectrum to be drawn in correct time sequence since portions of perviously drawn lines which should be hidden could be erased. The mechanism by which selective erase is accomplished by the hardware entails redrawing of the line to be erased in the erase mode. Thus removal of sections of previously drawn lines would require that a list of these segments be maintained in memory at all



times. Since it is not known in advance which segments will need to be removed, the entire display list would have to be saved in memory. Maintaining the display list in memory would require a relatively large amount of storage capability which was contrary to the goal of minimum memory utilization. Consequently, this approach was abandoned.

The second approach to hidden line removal and the approach that was implemented, requires that the frequency spectrum be drawn in reverse time sequence. While this approach may cause some confusion with regard to the time relationship between frequency spectrum, the amount of memory required to accomplish the hidden line removal is considerably reduced. The opaque surface approach to hidden line removal reduces the problem from the three dimensional problem discussed by Sutherland [15] to a two-dimensional problem which is much simpler to solve. Simply stated, the algorithm determines if at a particular horizontal coordinate, the new corresponding vertical coordinate is less than the maximum value for that point. If it is less, then a line should not be drawn to that coordinate position. If the new vertical coordinate is greater than the corresponding maximum, the line is to be drawn and the maximum value is to be updated to reflect this new maximum. This solution to hidden line removal is similar to the approach taken by Fuson [11] in his implementation of a SPOTLIGHT-like system on the Tektronix 4014-1 display terminal.

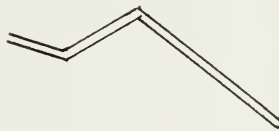






a. Hidden Line Removal Required

b. Coordinates Calculated



c. Line Drawn in one stroke

d. Maximum Levels Updated

==== Maximum Levels Previously Drawn

----- Line to be Drawn

figure 5: Example of Hidden Line Removal Algorithm



Unlike Fuson's solution, however, the algorithm utilized in this implementation utilized a variable number of sub-intervals when determining the cross-over point for line removal. Figure 5a illustrates a typical situation where hidden line removal becomes necessary. To determine the actual coordinates of the cross-over point, the slope of the new line is calculated and the vertical coordinates are determined for each subinterval horizontal coordinate (figure 5b). When these cross-over coordinates have been determined, a line is drawn to that point in one stroke. Since lines may only be drawn to discrete end-points, the actual crossover point may not be reached, which could result in an apparent gap in the drawn line. This is exaggerated in figure 5c for illustrative purposes. After the line is drawn, the maximum levels are also updated for subsequent comparisons (figure 5d).

This algorithm, while somewhat slower than Fuson's, was required to provide sufficient accuracy in a zoom mode. The accuracy was determined to be more important than the increase in speed enabled by a simpler algorithm.



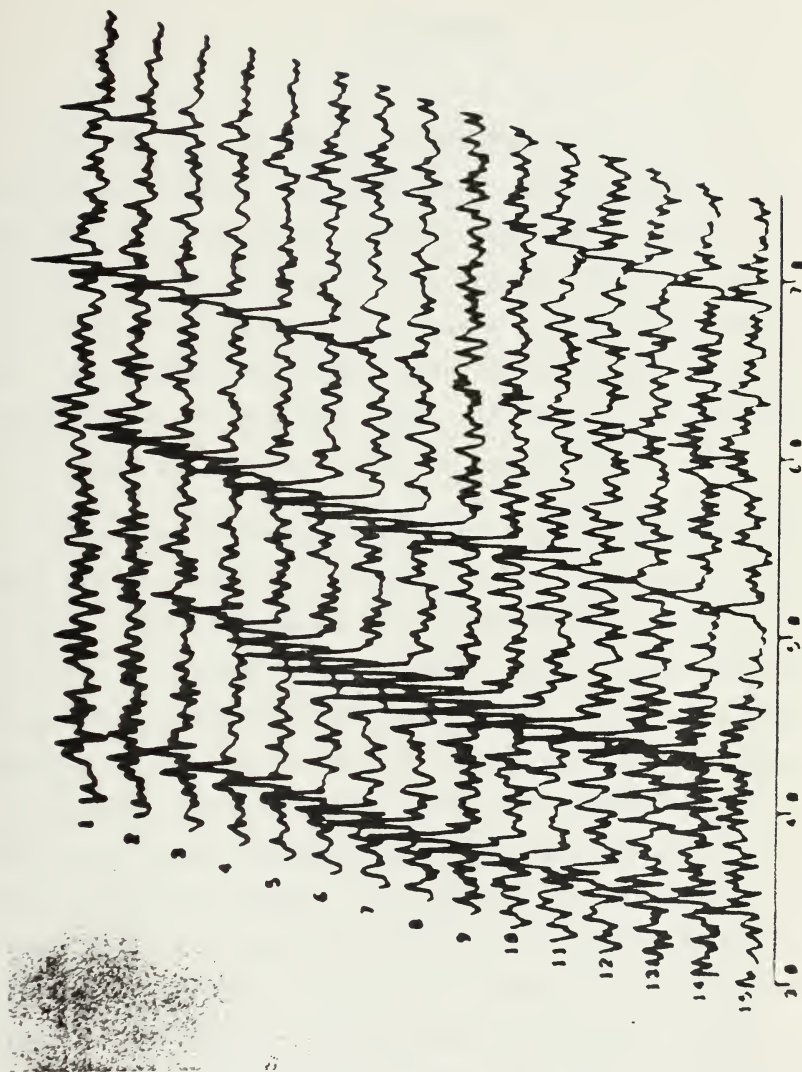


figure 6: An Example of Hidden Line Removal



## V. EVALUATION

To evaluate the PDP-11/50/CONOGRAPHIC-12 system as an alternative system for SPOTLIGHT implementation, it was necessary to evaluate the software required to operate the system as well as the hardware itself. The objectives of the software design were to provide a display format similar to the original SPOTLIGHT with similar user interaction capabilities, in software that was easily transportable while requiring minimum memory for execution.

The first of these goals, that of similar display format, was met with two exceptions. The first exception was that the displayed image on the CONOGRAPHIC-12 was static. Although the absence of the movable intensity cursor must be considered a significant drawback to the system as implemented, it is offset in part by the amount of data displayed at one time. In the original SPOTLIGHT implementation, a maximum of ten frequency spectrums were presented for analysis on the screen. The storage capability of the CONOGRAPHIC-12 display enabled considerably more data to be displayed. A maximum of thirty frequency spectrum were presented at one time for analysis. The number of spectrum that could be displayed was limited only by the physical size of the display screen.





The goal of similar user interaction capabilities was also met although the method of user interaction was modified somewhat due to the devices available for data entry. In the CONOGRAPHIC-12 system, all data entry was entered through a separate alphanumeric terminal. The primary reason for this method of data entry was a direct result of the permanence of the display image on the CONOGRAPHIC-12 terminal. Since any information displayed on the screen must be erased before it will disappear, using the CONOGRAPHIC-12 for data entry could result in the entire screen becoming cluttered with commands before any of the frequency spectrum could be displayed. In addition, the commands required to display text on the screen required considerable data manipulation to obtain the correct format. This would have increased the complexity of the software to an unacceptable degree.

The attainment of the goal of logical simplicity of the software was aided to a large degree by the use of a high level structured language. The use of the C language made both writing and debugging of the software much easier than if a lower level assembly language had been used as in the original SPOTLIGHT system. The use of a high level language will also aid the conversion of the software to other languages for use on other computers such as the AN/UYK-20.

One goal that was not attained to the degree desired was the that of minimizing the amount of memory required for execution. The hidden line removal algorithm and the



parameter input mechanisms required a considerable amount of memory for execution when compared to overall program size. The degree of accuracy desired in the hidden line removal algorithm was particularly costly in terms of memory requirements. However, increased accuracy over that necessary in previous implementations was dictated by the desire to minimize errors which could be detected when in the zoom mode.

In the area of hardware, the PDP-11/50 provided ample computing power to control the CONOGRAPHIC-12 display terminal in the signal processing environment. Although two processors were required due to the configuration that existed at the time of this evaluation, one processor would have been sufficient to control both the display and the data input. Storing the input data on an auxilliary disk unit, however, did provide one advantage to this implementation. While the data from the disk was modified to some extent to produce the actual display, that stored on the disk was not modified and was available for redisplay at any time. This eliminates the need to read the input data again if the operator desires to redisplay previous data.

The hardware capabilities of the CONOGRAPHIC-12 also proved to be sufficient to enable this terminal to be utilized in signal analysis. Capabilities of this terminal that were useful for this purpose included the video memory, the automatic refresh mechanism, the zoom capability, the movable cursor and the variable intensity feature. The video



memory and refresh mechanism enabled this terminal to display an amount of data limited only by the size of the display screen and the desired clarity of the display. By performing automatic refreshing of the display screen, the CONOGRAPHIC-12 relieved the host computer from the need to maintain a display list in memory for refresh purposes. This is a significant advantage over display systems which must be refreshed by the host computer.

The zoom capability provided a new dimension to signal processing on a graphics terminal. While a zoom capability may be implemented by software on most displays, this means of magnification requires that the displayed image be erased and redrawn. With the hardware zoom as designed in the CONOGRAPHIC-12 display, the picture may be magnified at any time without affecting the stored image. Thus the original image may be instantly recovered by the user. The magnification of the displayed image was especially useful in detecting details in the displayed frequency spectrum that might not be recognized on a non-magnified display.

Two other features that were available in the CONOGRAPHIC-12 hardware which appeared useful were the variable intensity and the movable cursor. The variable intensity feature was utilized in producing a highlight on the frequency spectrum display. However, the usefulness of this highlight could not be compared to that found in the original SPOTLIGHT system since a failure in the hardware disabled the variable intensity feature. At the time that this



evaluation was conducted, the problem had not been rectified. Since the variable intensity feature affects the stored image and therefore does not affect the refresh mechanism, an arbitrary number of highlights were capable of being displayed. Due to the hardware problems, however, only one highlight was implemented.

The other feature of the CONOGRAPHIC-12 terminal that appeared useful was the movable cursor that could be enabled programatically. It was desired to utilize the cursor in the single line mode to indicate a desired frequency. When the desired frequency had been selected, the frequency was to be evaluated and presented to the user. At this time the user was to have the opportunity to obtain the time behavior plot of the indicated signal. The actual implementation of the part of the program was also prevented by problems in the hardware.

The capability of the CONOGRAPHIC-12 to display textual material for labeling of the display was another feature that was hampered by faults in the hardware or software interface to the host computer. This is another problem that had not been solved at the time of this evaluation.

The CONOGRAPHIC-12 also had many hardware capabilities that were not utilized in this evaluation. The curve and conic section drawing capabilities were not needed to produce the display of the acoustic data for analysis. In addition, the selective erase capability which was present





was not utilized. One capability that is inherent in raster scan devices such as the CONOGRAPHIC-12 display that was not utilized but could prove to be of value was the ability to drive additional monitors. This would provide the capability of producing the same display image on the repeater monitors for use by several operators. This could be useful in an educational environment or to provide remote confirmation of the analysis of a displayed signal.



## I. CONCLUSIONS AND RECOMMENDATIONS

The Hughes CONOGRAPHIC-12 Graphics Display Terminal has been demonstrated to be a useful display system for signal processing and analysis. Both limitations and advantages of the display system have been discussed in the body of this thesis. To reiterate, the primary advantages include the increased data display capability, the zoom mode and the "black-on-white" display. The number of frequency spectrums that could be displayed at one time on the CONOGRAPHIC-12 terminal was limited only by the physical size of the display screen and the tolerance of the operator to image complexity. The zoom capability provided a new tool to the operator which could be extremely useful in detailed signal analysis. The "black-on-white" display provided a feature which could aid in system utilization since ambient lighting conditions would be less critical than with standard "light-on-dark" displays.

One advantage of the CONOGRAPHIC-12 that is inherent in any raster scan type terminal is the capability to drive other monitors. This feature could be useful in applications where several remote terminals must display the same information. By isolating the remote monitors from the host computer, the desired information must be transmitted to the "host" terminal alone. This would greatly reduce the amount



of computer controlled communications which in turn would free the processor for other tasks.

Disadvantages of the CONOGRAPHIC-12 that must be considered include the static nature of the display and the cost of features available on the terminal that were not utilized. The static display of frequency spectrum was not considered detrimental to signal analysis in light of the increased amount of information available for analysis. However, the capability of moving the highlight without redrawing the entire picture could not be provided since the display was static. Movable highlights were found to be a useful tool in previous implementations. One other disadvantage of the CONOGRAPHIC-12 terminal that should be considered in this application was the additional cost of hardware features that were not utilized. The selective erase and curve drawing capabilities that were provided in the terminal were not considered necessary in this implementation. Therefore, a terminal like the CONOGRAPHIC-12 without this additional hardware would be less expensive and just as effective in signal processing and analysis.

Further evaluation of the CONOGRAPHIC-12 terminal in areas of curve drawing and utilization of the selective erase capability is needed to fully realize the potentials of the terminal system. Signal processing and analysis is only one possible application.



Another area for further research in the signal processing and analysis is the possible use of color. The CONOGRAPHIC-12 provides a black and white display only. This required that highlighting be accomplished by varying the intensity of the line segment. In a color display system, use of contrasting colors might make the highlighting of signals more apparent to the user. In addition, related signals could be grouped by displaying them in a color different from that used for the rest of the display. Grouping the signals in this manner could aid the analyst in the analysis effort.

It is recommended that additional research be conducted in the area of computer controlled graphics terminals for signal processing and analysis. The SPOTLIGHT system and subsequent implementations have shown that alternatives to the lofargram are available and should be explored.





## APPENDIX A - USER'S MANUAL

Brief descriptions of the various parameters provided for user interaction with the PDP-11/50/CONOGRAPHICS-12 system are given in the main body of this thesis. The information contained in this appendix is intended to provide a guide to the user in the areas of parameter input, effects of the parameters on the display, and the allowed range of values for each parameter. Utilization of this system involves two stages which are data entry and signal processing and display. The first stage, data entry, may be skipped if the data for analysis is already present on the auxilliary disk storage unit.

### DATA ENTRY

This stage of the execution prepares the input data file for use in the signal processing and display stage of execution. Due to the hardware configuration that existed at the time of the implementation of this system, input data in the form of Fast Fourier Transforms of raw acoustic data must be read from 7-track magnetic tape and stored on disk for future access. This stage is accomplished on the B processor utilizing the 'rdtape' program. After the tape is loaded on the tape transport, execution may be commenced by typing user will then be asked to enter the length of the



transform. Integer values in the range from 1 to 32 may be entered, followed by a carriage return, corresponding to input data values from 1K to 32K. The execution of this program will then continue until the end of the data tape is reached. If for some reason, a section of the tape cannot be read, the affected transform will be skipped and execution will continue.

NOTE: If the disk unit RSM01 is not available for data storage, the user should make the appropriate change to 'rdtape.c' and then recompile this program before execution.

#### SIGNAL PROCESSING AND DISPLAY (SPD)

The signal processing and display stage of execution takes place on the A processor which interfaces with the CONOGRAPHIC-12 terminal. All command and parameter entries are performed on an alphanumeric terminal rather than the CONOGRAPHIC-12 terminal itself. Prior to commencing execution of the SPD program, the CONOGRAPHIC-12 terminal should be cleared of any error conditions which might exist from powering up the display or the previous use of the terminal by another program. Clearing the terminal is accomplished by selecting LOCAL mode, momentarily depressing MACHINE CHECK, entering CNTL X (CAN) on the keyboard, redepressing MACHINE CHECK and then deselecting the LOCAL mode.

During the SPD stage of the execution, three phases will be encountered. These are the initialization phase,



command phase and execution phase. When in the initialization phase, the user will be requested to enter transform length, lag and sampling rate of the input data if any of these values differ from the default values that are provided. In addition, the user will be requested to enter the data start time before execution can continue. After initialization is complete, the program will enter a command phase where the user will be afforded the opportunity to modify parameters for display control as desired. While in the command phase, the user will also be afforded the opportunity to request help from an on-line assistance file which will provide a brief description of each of the variable parameters as well as normal values and the allowed range of values. After all parameters have been modified as desired in the command phase, the program will enter the execution phase which performs the processing necessary to provide the display in accordance with the parameters that have been set. No further user interaction is required until the program completes the display and returns to the command phase.

To commence execution of the SPD stage, the user simply types 'conspd' (without quotes) followed by a carriage return.

NOTE: If the disk unit RSM01 is not available for data storage, the user should make the appropriate change to the source program and recompile it with reference to the CONOGRAPHIC-12 software interface routines.



## A. SPD Initialization Phase Parameters

### 1. Transform Length

default value: 8K

description: The transform length indicated by the user should match the transform length of the input data.

range: 1 to 32

### 2. Lag

default value: 1K

description: The lag between transforms indicated by the user should match the lag in the input data.

range: 1 to 16

### 3. Sampling Rate

default value: 128hz

description: The sampling rate indicated by the user should match the sampling rate in the input data.

range: 1 to 1024

### 4. Continue

description: Selecting this parameter indicates that the transform length, lag and sampling rate have been modified as desired by the user. The computer will now prompt the user to input the desired data start time in the format hh:mm:ss where hh indicates the hour (based on 24 hour clock), mm indicates the minutes and ss indicates the seconds. All





three entries must contain 2 digits separated by a non-digit such as ':':

range: 00:00:00 to 23:59:59

## B. SPD Command Phase Parameters

### 1. Display Time

default value: data start time

description: The display time is the time on which each display page is based. The topmost frequency spectrum on the page (or only one if in single line mode) is associated with the display time, and the other spectrums displayed progress in time increments equal to the lag / sampling rate in seconds. The display time must be equal to or later in time than the data start time. Time intervals which cross the 24:00:00 boundary are automatically compensated for by the program. The format for entering the display time is the same as for data start time.

range: 00:00:00 to 23:59:59

### 2. Frequency to be displayed

default value: 0.00hz

description: The frequency to be displayed is the frequency on which each spectrum is based. The entered value is on the left end of the spectrum with frequency increasing to the right. The axis displayed on the screen is graduated in one hertz increments. The value entered for the frequency should be in floating point notation.



range: 0.00 to one half of the sampling  
rate

### 3. Scale Factor

default value: 20

description: The scale factor provides amplitude scaling of each frequency spectrum. The overall shape of the spectrum is maintained, only the relative amplitudes are changed. Smaller values The scale factor as entered is utilized as a divisor. Therefore, smaller values result in increased amplitude of the displayed signals.

range: 1 to 1000

### 4. Display Resolution

default value: 5

description: The display resolution provides horizontal scaling of the displayed frequency spectrum. The physical length of the displayed spectrum remains constant, so the resolution has a direct affect on the bandwidth which is displayed. A low value of resolution will result in a wide bandwidth, and a high value will produce a narrow bandwidth. The actual bandwidth which is displayed is determined from the following formula:  $\text{bandwidth} = (1440 * \text{sampling rate}) / (\text{transform length} * \text{display resolution})$

range: 1 to 10



## 5. Angle Offset

default value: 60(degrees)

description: The angle offset is utilized to skew the display away from a vertical representation. This is useful for observing trends in signal amplitude variations and in analyzing signal that might otherwise not be visible due to hidden line removal. The angle of offset is measured from the horizontal axis.

range: 60 to 90

## 6. Number of Lines

default value: 30

description: The number of lines parameter determines the number of frequency spectrum that will be displayed at one time. If the number of lines selected is two or more, the requested number of spectrums will be displayed. However, if a single line is requested, another feature of the program is enabled. When prompted by the computer, the user may enter a frequency (in floating point notation) and a time verses amplitude plot of that frequency will be provided. The time plot will be based on the specified display time and will show the amplitude of the requested frequency over the following thirty time increments. A maximum of four time plots are available at one time.

range: 1 to 30



## 7. Vertical Separation

default value: 5

description: This parameter provides variable vertical spacing between frequency spectrums. Increasing the spacing may add to the clarity of the displayed image and also decrease the effects of hidden line removal. However, spacing the spectrums too far apart (depending on the spectrums) may cause a loss of visual continuity between spectrums and make recognition of trends in signal amplitude more difficult. The physical size of the screen dictates that the user compromise between the number of lines and the vertical spacing to enable all of the requested data to be displayed.

range: 0 to 30

## 8. Highlight

default value: off

description: Selection of the highlight mode enables two further inputs which are width of the highlight and the frequency of the highlight. The highlight provides the user with a frequency reference on each spectrum in the form of a more intensely drawn segment. This reference is most useful when the display is offset from vertical. Entering a zero width will turn the highlight feature off. NOTE: The highlight feature should be the last change made to the parameters before execution.

range: width: 0 (off) to four times the display resolution  
frequency: within the frequency





bandwidth to be  
displayed

9. Continue  
description:

This parameter causes the program to leave the command phase and commence execution. A maximum delay of approximately 20 seconds may be expected before any drawing takes place on the screen.

10. Exit  
description:

Selection of this parameter will cause the program to terminate.

11. Help  
default value:

off

description:

Selection of this parameter causes the program to enter the on-line help function section. In this section, brief descriptions of each of the preceeding parameters may be obtained by entering the desired name as shown on the list provided upon entry to the help function. The descriptions given are similar to the descriptions found in this User's Manual.



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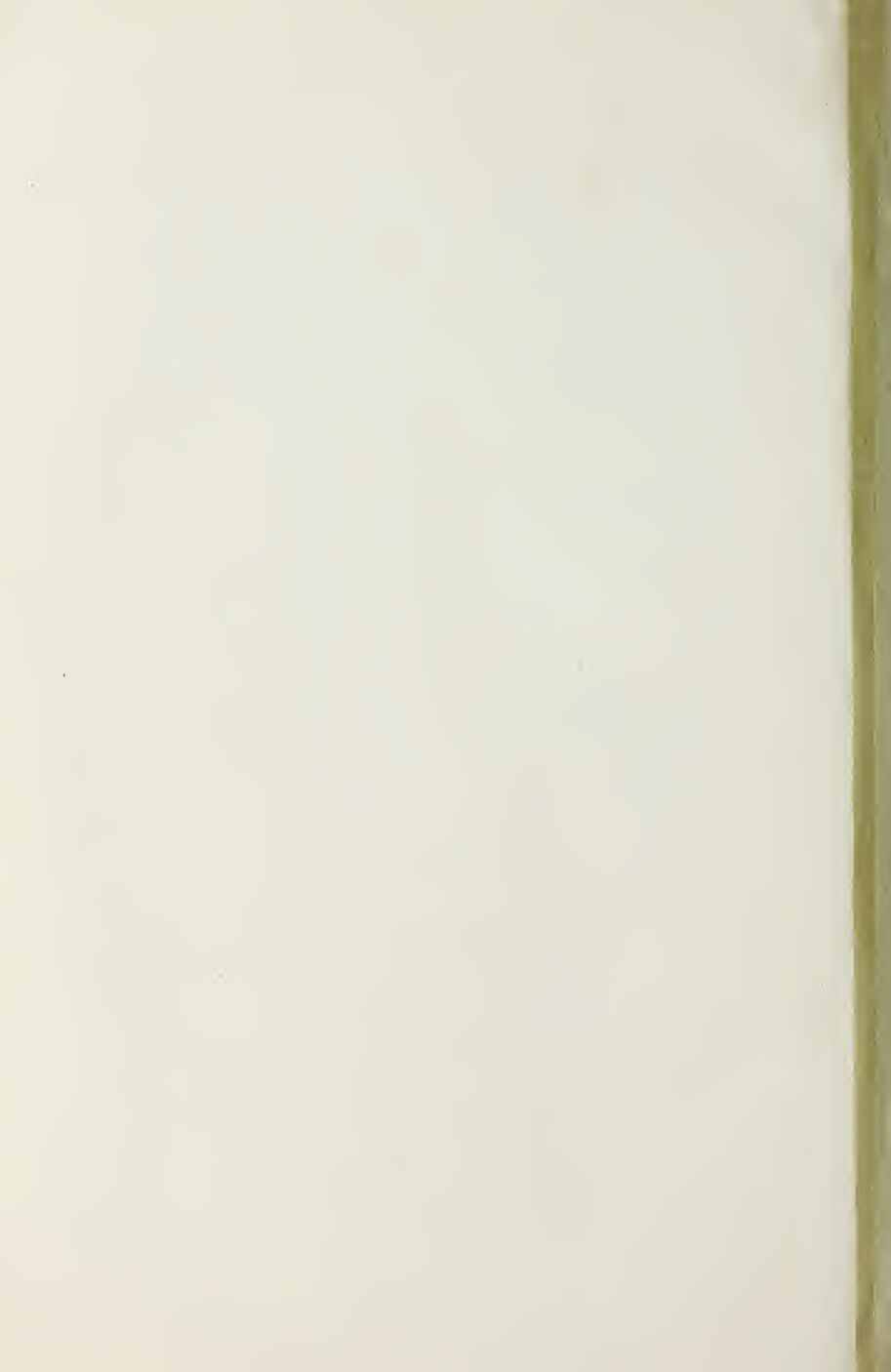












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